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Abstract
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VITAMINES ON THE FARM

Their Practical Relation to Livestock Feeding

BY ALVIN R. LAMB AND JOHN M. EVVARD

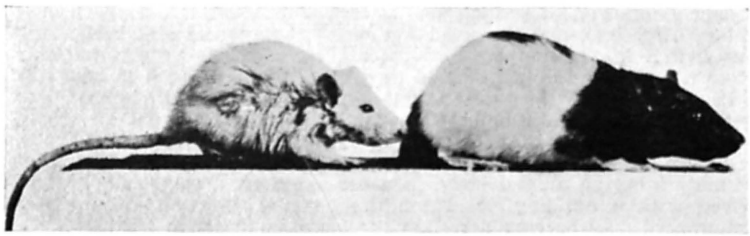

Fig. 1. These rats, both the same age, received the same rations, except that the one on the right received butterfat and the rat on the left received a vegetable oil which did not contain vitamine A. (From McCollum).

When a practical feeder, trained in the school of experience, asks, "What are vitamines, anyway?" and "What do these rat-feeding experiments have to do with feeding pigs?" he deserves a fair answer. While the study of vitamines in the experiment stations has uncovered facts of much value to the livestock man, it is possible for those who are over-enthusiastic to emphasize too highly in some cases the importance of vitamines to animals fed under average conditions. It is essential to discover where emphasis should be laid upon vitamines under practical feeding conditions.

There are certain conditions under which the question of vitamine supply becomes very closely related to the pocketbook of the producer. Then there are other conditions, as when livestock is on a good alfalfa or clover pasture, when the vitamines are assured by the pasture. The fact that there are certain circumstances, especially in swine husbandry, when the ration should be so planned as to take care of the vitamine supply, should be given careful consideration by the feeder. He should not be blind to this important factor, even tho the importance of vitamines under practical conditions is, like other new discoveries, sometimes overestimated and over-emphasized.

Fig. 2. This rabbit received a ration containing no vitamine A. The eyelids are swollen shut. This condition was quickly cured by adding butterfat to the ration.

HOW VITAMINES WERE DISCOVERED

The wonderful discoveries which have been made in nutrition during the last decade or so were not made by chemical work alone, but by experimental feeding tests with carefully purified rations* and on the animals themselves. In all these tests the animal has itself been the court of last resort as to what its body needed for growth. The story of what was learned in these feeding experiments with purified feeding stuffs is very interesting and will be told briefly.

A great deal has been said and written in the past about balanced rations. The importance of balancing the protein in the ration with the proper amount of fat and carbohydrate was discovered and appreciated a long time ago, and the need for such a balance is still recognized, but now it is known that the matter of providing a proper and complete ration is more complicated than merely balancing it in this way.

It was formerly considered that a ration in order to be complete needed only a certain amount of protein, a certain amount of mineral substances, and a certain amount of fat and carbohydrates to furnish energy. To understand clearly the part played by each of these kinds of materials, the animal body, in a certain limited way, may be compared with a building, in which the concrete foundation and steel framework may be considered as the bony skeleton, and the brick or stone walls be likened to the muscle tissue which makes up the greater part of the body structure. The analogy may even be carried far enough to compare the exterior decorations and interior finish, which make the building habitable and more than a mere shell, with the fatty tissue in the body, a certain amount of which is useful and helps to keep the body structure warm.

If the comparison could be carried far enough to say that when a few bricks on the outside were worn off by the weather, the building could grow them on again if the proper bricks were supplied, there would be an analogy of the continuous wear and repair of the animal body. It must be remembered that bricks of proper size and style are necessary for this repair work, in just the way that protein for body repair must contain certain substances which are comparable to the bricks needed. A consignment of bricks or building stones might not contain the best assortment of the kind of building material needed for the repair work, just as all food proteins are not alike in furnishing the proper materials for body repair or economical growth. This was one point on which former knowledge of nutrition was incomplete; that is, when it was thought that any food protein was equally good for this purpose of growth or repair in the animal body.

In this repair work, some of the same mineral constituents found in the concrete foundation of the building must, in the form of mortar, be used to hold the bricks together. Certain mineral substances are necessary and cannot be substituted in the mortar. It is likewise true that certain minerals, some of which are found in the bony skeleton of the animal body, are absolutely essential thruout the rest of the body structure. One of these essential minerals for both the body and the building happens to be lime, and if that or any other essential mineral is not present in the food in sufficient amount, the body welfare is interfered with.

As the protein has been characterized as structural material, so the fats and carbohydrates, the sugars and starches of the food, may be described as the fuel. In order to make this imaginary building habitable or alive, it must be heated, and the coal or wood used for

*By "purified ration" is meant a ration which is not made up of the natural feeding materials as they are found in grains and forage, but of purified protein, purified carbohydrates and pure mineral salts.

this purpose would compare to the fats and starches in the food which are burned in the body to keep it warm. In case of necessity, some of the interior furnishings of the building may be burned, just as the body will use its own tissue for energy if food is not furnished. In the animal body, the protein, which may be compared to structural lumber instead of stone in the walls of the building, may also be burned in the body to furnish heat or energy.

Since it has been found that only a very small amount of vitamines is necessary for an animal, there may even be an analogy in this imaginary building for the vitamines. They may be considered as a necessary component of the mortar which holds the bricks together in the wall, or perhaps as the matches with which to light the fire, without which the fuel would be useless.

ANIMAL FEEDING TESTS

Theorizing does not go very far in considering the nutritional needs of the animal body. All that is actually known on this subject has been learned from feeding tests on animals. The beginning of real progress was made about ten years ago, when Osborne and Mendel, at the Connecticut Agricultural Experiment Station, and McCollum, at the Wisconsin Experiment Station, began feeding large numbers of laboratory animals, practically all rats. Naturally, it would be a long and expensive process to feed purified rations to farm animals. By feeding these rats various carefully purified rations, it was found that a ration containing a pure protein (casein, the curd of milk) pure starch, pure sugar, and a mixture of pure mineral salts, absolutely failed to produce growth in the rats. In this carefully purified ration altho the protein was of the very best quality and enough minerals were present, there was apparently something lacking, as the rats failed entirely to grow, even when a fat like lard or olive oil was added to the ration. But when butterfat or egg-yolk fat was added to this ration, the rats grew, and they grew even when a small amount of an extract of these fats was given them. Evidently something necessary was found in these fats which did not occur in all fats. This unknown thing is called one of the vitamines, or "fat-soluble A."

Altho the rats grew on this ration, their growth was not normal until another vitamine was added, in the form of an extract of wheat germ. This second vitamine is now generally known as "water-soluble B", and was later found to be the same vitamine which is lacking in the diet of Asiatic people who develop the disease known as beri beri, while living on a diet consisting largely of polished rice. Since this vitamine is located mainly in the germ or embryo of the rice, which is removed in milling by rubbing off the bran layer, this disease is caused by eating largely of the polished rice, without eating the vitamine in some other form. Another disease, which attacks the eyes, is caused by a lack of the other vitamine mentioned, "fat soluble A", and will be discussed later, as it is of much interest.

NUTRITIVE RATIOS AND FEEDING STANDARDS

The statement is sometimes made that "science is always changing", and many are inclined to place little confidence in conclusions of this sort. As a matter of fact, while scientific progress sometimes discards older theoretical ideas, and occasionally declares them untrue, it does not discard established facts. It is seldom, if ever, that science reverses itself. It merely goes on farther in learning the truth about the laws of nature. Thus, in the light of the newer knowledge of nutrition, nutritive ratios and feeding standards for farm animals have not been discarded, but it has merely been learned that they do not

tell the whole story. It is now possible to use these standards more intelligently than formerly, keeping in mind, in addition to considerations of palatability and bulk, the fact that all feeding materials are not of equal value, and that the animal needs good protein, a well constituted mineral mixture, enough vitamines, and sufficient net energy-yielding feed.

WHAT ARE VITAMINES?

No one can say just what vitamines are. Neither can anyone say just what electricity is, but both are known by what they do. It is known that vitamines are absolutely necessary for growth and health in an animal, and a good many foods which contain them are also known. No one, however, has, as yet, been able to get a vitamine out of a food and look at it,—but that does not make the fact of the existence of vitamines uncertain.

Vitamines are known by the effects on the animal caused by thei presence in or absence from the ration. If a rat, under controlled laboratory conditions, is fed a diet of purified casein, starch and mineral salts, it will not be receiving any vitamine and will not grow, except for a very short time. Death will follow if vitamines are not added to the ration. The first or fat-soluble vitamine, sometimes called vitamine A, may be added to this ration by putting in a little butterfat, perhaps only 1 percent of the ration. The other necessary vitamine, water-soluble B, or vitamine B, may be added in the form of a little wheat germ, or by adding a little dried yeast, which contains very much of the vitamine B. If either the butterfat or the yeast are left out of the above ration, the rat will not live very long. The striking results obtained are illustrated in fig. 1. The stunted rat received all the essential factors in a complete ration except vitamine A, the one which is found associated with certain fats, especially butterfat.

The next illustration, fig. 2, shows the effect on a rabbit of feeding a ration which is complete in everything but this same vitamine A. A very characteristic eye disease results, which has long been known to occur in rats on such a ration, but which was first produced in rabbits at this station.* The rabbit in fig. 2 received a ration of casein, dextrinized or partly digested starch, salts, a little wheat germ, and alfalfa meal, extracted with alcohol to remove the vitamines. About eight weeks after being put on this ration, the rabbit developed this eye disease, and would have died soon, as the other rabbits did, if it had not been cured by adding a little butterfat to the ration. Cod-liver oil, egg-yolk, or an extract of green leaves would also supply this vitamine and cure the eye disease, which is generally called xerophthalmia. Since farm animals do not receive the first-named materials, they obtain this vitamine mainly from green plants. However, a small amount of it is found in the germs of seeds, but generally not enough to supply the needs of the animals.. Yellow corn and soybeans are carriers of this vitamine A.

The pigs shown in fig. 3 received a ration consisting mainly of white corn, with some oil meal, a little oats, a little tankage, and a salt mixture containing lime. This ration is good in all respects except that it is low in fat-soluble vitamine, or vitamine A. Their appearance, rough coat, and failure to grow on this ration, demonstrate their need for this vitamine. If they had been allowed a little green stuff or good pasture, they would have grown well. Yellow corn instead of white would have been better, as it contains more of vitamine A, but they would have done still better on green pasture, preferably leguminous.

Further experiments are now under way at this station to determine

*This test was carried out in cooperation with Professor V. E. Nelson of the Department of Chemistry, Iowa State College.

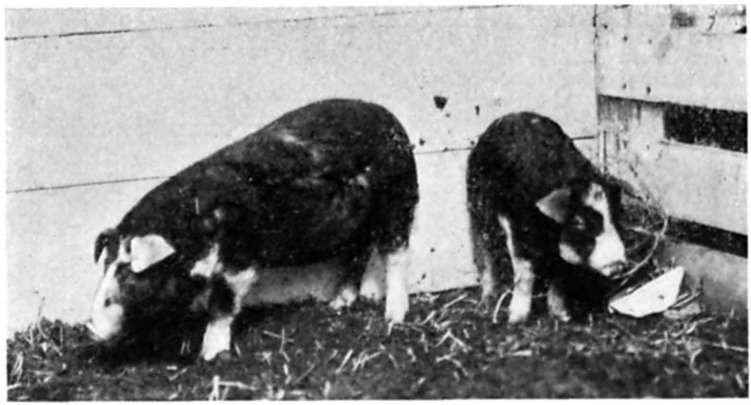

Fig. 3. These pigs received a ration in dry lot consisting mainly of white corn, oil meal, oats, tankage and lime salts, adequate except for vitamine A. They weighed only 30 pounds at four months of age.

more carefully the difference between yellow and white corn in vitamine content when fed to pigs under the same conditions as in this experiment. After this photograph was taken, one of these pigs was given a spoonful of butterfat daily, with markedly good results. He improved in appetite, gained weight, and became very thrifty, while the other pig continued "down hill". The contrasting appearance of these pigs later is shown in fig. 4. The smaller pig on the right in fig. 3, which was nearly dead when the butterfat feeding was begun, became the well nourished, smooth-coated animal on the right in fig. 4. The best practical source for the necessary vitamine in this case would have been rape, clover, or alfalfa pasture, but the results obtained by feeding a small amount of butterfat show plainly that pigs must re-

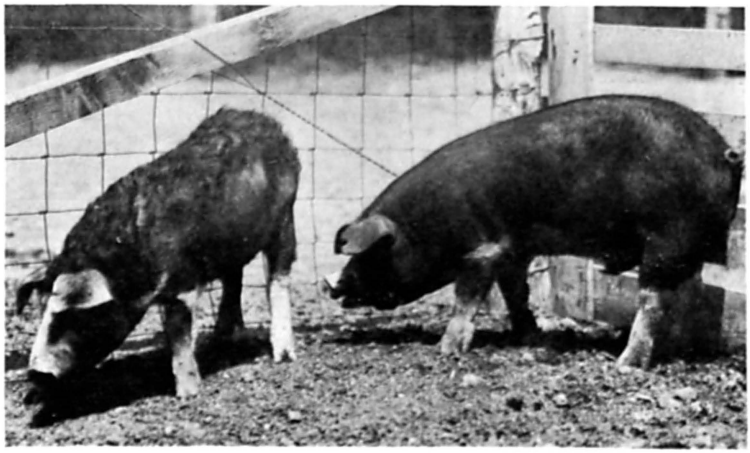

Fig. 4. The addition of one spoonful of butterfat daily to the ration of the pig on the right in fig. 3, in four and one half months transformed him to the thrifty animal shown on the right here.

ceive enough vitamine from some source, if growth and health are to be maintained.

These results indicate that the kind of ration fed pigs in dry lot should receive careful consideration. Pigs are of all farm animals the most likely to be fed rations which are deficient in one way or another. Of course, their rations are often deficient in other things than vitamines, and pigs almost always respond well to additional lime with their feed. But if they do not have good pasture or other green feed, they will probably suffer from too small a supply of vitamines, as well as from a deficiency in minerals. This shortage of vitamine is generally not great enough to produce such effects as shown in the illustration, but it is factors like this that make a great difference in economy of meat production, and sometimes spell the difference between profit and loss. Probably very few pigs actually die from a lack of vitamines, but no careful feeder who wants profits should overlook the value of green feed, or feed too long in a dry lot with no vegetation.

Other farm animals, cattle, horses and sheep, which consume large amounts of hay, grass, or silage, probably secure an abundant supply of vitamines in this manner. Thus it appears that their vitamine supply is adequate, except where a restricted ration is fed. It should be remembered, however, that not all hay is equally good. For example, one reason for the well-known fact that timothy hay is of very much less feeding value than clover or alfalfa, is the small amount of leaf in timothy hay as it is usually cut. It is the green leaves of plants which are rich, not only in vitamines, but also in proteins and minerals. This has been repeatedly shown in experiments on small laboratory animals, and by chemical analysis, and is confirmed by experience with meat-producing animals. The lack of leaves in timothy hay is therefore one reason for its poor quality.

Even for animals which consume considerable roughage, there may be times when poorly chosen rations would be too low in vitamines. An illustration of this would be an attempt to winter growing colts on a ration of corn or oats and timothy hay. The effect of the deficiencies in this ration would show more in a growing than in a mature animal. Of course, the ration mentioned above would be poor in minerals, as well as vitamines, and none too good in protein.

Straw as a roughage is very poor indeed. It has been thoroly demonstrated at the Wisconsin station that a sole ration of oats (grain) plus oat or wheat straw stands a small chance of producing live calves if fed to cows a year or more before calving. The chief faults in such a ration are lack of vitamine A and deficiency in minerals. Such a ration can be made satisfactory by the addition of some clover or alfalfa hay, which supply plenty of lime and other minerals, as well as vitamines.

VITAMINES B AND C

The vitamine most likely to be deficient is vitamine A, because it is least widely distributed in natural foods. The defective rations discussed above are lacking mostly in vitamine A. The vitamine B, which occurs in large amounts in yeast and germs of seeds, also occurs in all other natural feeding materials, so it is generally thought that a deficiency of this vitamine probably rarely occurs. However, future experiments should definitely settle this point. In the human dietary it might be deficient in amount if highly milled grains form too large a part of the diet, and other natural foods, such as potatoes, roots, and fruits, are not eaten. This is often the case in oriental countries, but rarely in America.

The third vitamine, or vitamine C, the anti-scurvy vitamine, is not so well known as the others. As far as known at this time, only one

or two species of animals besides the human family show a definite need for vitamine C. The guinea pig is the animal which shows the greatest need for this vitamine, as it develops scurvy in a short time unless fed green leaves or fruits which contain the unknown substance which protects against that disease. The human infant generally needs this substance, and it is usually given in orange or tomato juice. This is necessary, because milk, either cow's or human milk, which is so nearly perfect a food, does not always contain enough of this particular vitamine, depending mostly on the character of the feed eaten by the animal which furnishes the milk.

In connection with these two vitamines some work has recently been reported by Evvard and Glatfelter of the Iowa station, on raising orphan pigs. Feeds which contain the vitamines B and C were added to the cow's milk which was given the pigs at the rate of one quart per day. Yellow corn, tankage, and salt were offered the pigs in self-feeders, and they began to eat these at an early age. One lot of pigs received, in addition, the juice of one orange per pig per day; one lot received one egg per pig per day; one lot received 5 ounces of tomato juice; one lot received 4-5 ounce wheat germ, and one lot received milk alone. At the end of 90 days, the lots receiving materials high in vitamine showed much greater gains than the check lot on milk alone. While it is true, of course, that in adding these materials to the milk many other things than vitamines were added, it is significant that these high-vitamine foods gave such good results.

OTHER FACTORS IN NUTRITION

As stated above, not all proteins are equally good for growth or repair in the animal body. The feeding tests with rats showed that the proteins of different feeding stuffs are of different value in nutrition, on account of their variable composition. As was suggested in the comparison of protein feeding with the task of building a house according to specifications, with various kinds of brick or building-stones, proteins must be fed which contain all the necessary substances or compounds which are needed by the animal body. These experiments with rats showed that the cereal grains, which are highly prized in feeding, particularly for their high energy content, are not complete enough alone, for satisfactory growth, in either protein, minerals, or vitamines. That is, an animal cannot grow properly on a ration of wheat, oats, or corn, alone, but must also receive better protein, more vitamines, lime, and common salt. Pasture grass or any green plant leaves or good hay will furnish supplementing protein, more vitamines, and some minerals, and, therefore, hay, especially the legumes, green pasture, and silage, are logical supplements for the grains. For pigs, good tankage does very well as a supplement to corn in supplying minerals and protein, but pork can be produced still more rapidly and economically if alfalfa, rape, or clover pasture is also allowed.

The remarkable value of milk and milk products has been very strikingly shown by feeding tests with pigs and rats. An animal which has stopped growing on a ration of wheat or corn alone shows a wonderful change when good milk is added to the ration, even in comparatively small amounts. Practically all the deficiencies of the grain are made good by the milk, or even by buttermilk or skimmilk. Whey, altho its protein content is lower, is a good supplement in this respect, especially for vitamines and minerals. In a community where dairy by-products are available at a reasonable cost, they are most economical as well as efficient, especially for feeding swine. Everyone should know of the value of milk and dairy by-products for both farm animals and human beings. Altho milk has come to be famous for its vitamines, it is even more valuable and dependable for the high

quality of its protein and its content of necessary minerals, especially lime, which is so often deficient in the ration of both pigs and humans.

In connection with the food value of milk, it is worth remembering that any real substitute for milk must contain the same nutritive qualities as milk, especially vitamines, proteins and minerals. It has been found in the course of laboratory experiments such as have been described that green leaves of most plants contain all these necessary elements for complete nutrition. They are therefore a worthy substitute for milk in a ration or in a human dietary. There have been, however, recent attempts to prepare a "cowless milk" from cereals, such as oats, peanuts, etc. All seeds, including cereal grains, are deficient, unless supplemented, in quality of protein, vitamine A, and minerals, especially lime. The deficiencies of corn grain which cause its well-known failure as a sole ration for growing pigs, are shared by other cereal grains and other seeds. Therefore, any preparation made from these materials, even tho it looks like milk, is not milk, and is not necessarily a suitable substitute for milk in the diet.

It must be remembered that vitamines, as well as the other factors discussed, are of much importance in promoting health, vigor, and resistance to disease, as well as on account of their more obvious influence on growth. It is as important for a mature animal as for a growing animal to be properly nourished, especially since it has been proved that its resistance to disease is thereby increased. However, too much emphasis must not be placed on vitamines as compared with the other factors described here, for the lack of sufficient good protein or minerals in a ration will cause as much trouble or loss of efficiency as insufficient vitamines.

Furthermore, it is also certain that the nearer rations are to the natural condition, that is, not milled nor separated from the rest of the plant, the more likely they are to be complete. This is true also of the rations of carnivorous animals which eat other animals. Instead of eating only the muscle tissue, or the steaks, of their kill, they also take the blood, the liver, and the other internal organs, and gnaw the bones thus getting a complete ration. So with plants, corn grain, for instance, separated from the rest of the plant is an incomplete ration, while the whole plant, as put into the silo, is a complete ration for cattle, even tho it is not a concentrated one nor one that would be economical to feed without other feeds, such as protein supplements.

POINTS TO BE REMEMBERED ABOUT VITAMINES

1. Vitamines are necessary for mature as well as for growing animals, to promote health, vigor and resistance to disease.

2. Growing animals show the lack of vitamines sooner than mature animals. Reproduction also demands a sufficient supply of vitamines in order to be successful.

3. The vitamine least widely distributed and most likely to be lacking is vitamine A, the principal known sources of which are butterfat. egg yolk, cod-liver oil, green leaves of plants, and in less amounts, certain seeds, for example, yellow corn and soybeans. It is also found in small amounts in the germs of practically all seeds. As far as is now known, it is the one vitamine most likely to be low in ordinary farm rations, especially when good pasture is not supplied.

4. Vitamine B, the one found in yeast and in germs of seeds, is less likely to be deficient in amount in rations, because it is widely distributed in all natural foods. Yeast, which is often used as a source of vitamine B, also contains other things which may prove to be of value in certain conditions.

5. In planning production rations, it must be remembered that an animal requires, besides vitamines, liberal water, an abundant supply of good protein, a sufficient net energy content and a complete supply of mineral elements, especially lime and salt.